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Science and Technology for Tomorrow's Aerospace Forces

Success Story

MEMS IMU CALIBRATION AND ALIGNMENT PROGRAM

The Microelectromechanical systems (MEMS) inertial measurement unit (IMU) calibration and alignment (MICA) transfer alignment algorithm benefits any MEMS IMU exhibiting 50-200°/hr gyro drift rates and up to 10°/hr bias in-run stability errors. The algorithm allows an aligned and calibrated MEMS IMU to navigate with accuracy similar to that of a conventional tactical-grade IMU during the weapon's post-alignment trajectory. Improved navigation accuracy provides a technology transition opportunity to weapons programs (like the Wind Corrected Munitions Dispenser program) that require near-tactical grade weapon accuracy for relatively short weapon delivery trajectories.

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Accomplishment

The Munitions Directorate, in partnership with System Dynamics International, recently completed the first ever F-16 flight tests of a MEMS IMU. The flight tests demonstrated the viability of MEMS IMU technology and the effectiveness of an innovative transfer alignment algorithm called the MICA algorithm.

Researchers designed the MICA algorithm to accurately align the MEMS IMU and substantially calibrate its low-grade (100°/hr) MEMS gyros using data provided by the aircraft's inertial navigation system. The MICA algorithm consists of a conventional integrated velocity-match Kalman filter augmented with yaw attitude-match measurements and two associated filter state variables.

These innovations provide a continuous calibration of the yaw gyro and suppress IMU heading error growth during the low-dynamic cruise segments of the aircraft's alignment trajectory. After a successful series of laboratory and van tests, F-16 captive-carry flight tests demonstrated that the low-grade MEMS IMU, when aligned and calibrated with the MICA algorithm, achieved unaided navigation accuracy comparable to a 5°/hr optical-gyro IMU.

Background

The Air Force Research Lab and Defense Advanced Research Projects Agency are currently pursuing several programs, which specify requirements for small, low-cost IMUs for tactical air-launched weapons. Specifically, investigations are under way to determine the suitability of MEMS sensors and ultimately MEMS-based IMUs for these applications.

Currently, MEMS gyro errors are approximately one to two orders of magnitude larger than those associated with the more mature and costly optical gyro IMUs (e.g., ring laser gyros and fiber optic gyros). For most tactical weapon systems, these large MEMS gyro errors induce prohibitively large weapon miss distances (hundreds of meters), virtually eliminating MEMS IMUs from serious consideration.

Ongoing research efforts to develop a practical 1-10°/ hr MEMS gyro are several years away from completion. However, the Air Force recognized near-term MEMS IMUs as viable candidates for tactical weapon systems if researchers developed an advanced algorithm to reliably calibrate and align the MEMS IMUs during prelaunch transfer alignment. This approach provides a software solution to a current hardware limitation, thereby allowing system designers to use small, low-cost MEMS IMUs without sacrificing weapon system performance.

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Additional information

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